

SOIL ANALYSIS BY MEANS OF A 1:2 VOLUME EXTRACT

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SUMMARY

The use of the 1:5 weight extract in soil analysis presents some difficulties. Conductivity determinations as a means of assessing the salt status are unreliable for those soils containing appreciable amounts of gypsum, and it is also desirable that the soil organic matter content be known when interpreting the analytical data.

These objections are largely overcome by using saturation extracts. The principal drawback with this method is, however, its laborious procedure.

In an investigation at the Experiment Station at Naaldwijk very good results were obtained using an extract made by adding sufficient field-moist soil to two parts of water until the total volume had increased by one part (1:2 volume extract). The analytical data for conductivity, chloride, nitrogen, phosphate, potassium and magnesium in this extract were very closely related to data obtained by the saturation extract. The correlation coefficients being between 0.943 and 0.982.

The weight ratio water: soil of the 1:2 volume extract was highly correlated with the organic matter content. In soils low in organic matter the ratio was about 1:1, and with very peaty soils (40 per cent organic matter) about $3\frac{1}{2}$:1.

For precise preparation of the 1:2 volume extract it is necessary to use soil samples at field capacity. A visual check on this condition appeared to be possible.

INTRODUCTION

Soil analysis plays an important role in glasshouse management. Because of the rapid changes which occur in both the salt and nutrient status it is desirable that frequent determinations are made, and this results in a considerable number of soil samples for testing. At the Experiment Station at Naaldwijk, for example, more than 40,000 soil samples are tested each year.

Testing for salt and nutrient status is usually carried out by means of a water extract of the soil, the extraction ratio normally used being one part by weight of air-dry soil and 5 parts of water (1:5 weight extract). Electrical conductivity and chlorides are used to assess the salt content, and the nutrient status is assessed from the concentration of nitrogen, phosphate, potassium and magnesium.

The 1:5 weight extract does, however, have some disadvantages. In interpreting the analytical data it is desirable to know the moisture content of the soil when at field capacity, and this can be derived from the organic matter content². Thus the interpretation of the analytical data for conductivity, chloride, nitrogen, potassium and magnesium is made in relation to the organic matter content. Phosphate is usually evaluated independently of the organic matter. With increasing water: soil ratio the concentration of phosphate in solution tends to be more or less constant as a result of the large reserves in the soil and their low solubility. Only if the water: soil ratio is raised to a high value can a significant decrease in concentration be expected⁴. The concentration of phosphate in the 1:5 weight extract generally equates with the phosphate concentration in the soil solution.

Another disadvantage of the 1:5 weight extract is that the conductivity of the extract gives an erroneous impression of the salt status on those soils which have a high gypsum content. This is due to the fact that whilst the solubility of gypsum is low, appreciable quantities are dissolved at the high water: soil ratio of the 1:5 suspension. This problem frequently occurs with glasshouse soils.

The objections mentioned above are largely eliminated by using saturation extracts³ which have been shown to relate closely to the composition of the soil solution². A practical disadvantage of this method is, however, the laborious preparation.

During research to develop simple and reliable methods of assessing the salt status encouraging results were obtained using an extraction method developed by Japanese workers^{6,7}. In this method the extract is prepared by filtration of a suspension obtained by adding sufficient soil to two parts of water so that the total volume is increased by one part (1:2 volume extract). The soil was not dried in advance, but used in field-moist condition. Conductivity and chloride concentrations found with this method were highly correlated with the data obtained from saturation extracts; a correlation coefficient of 0.984 was obtained for conductivity and 0.987 for chloride content. Thus the disadvantages apparent in the 1:5 weight extract were largely eliminated with the 1:2 volume extract.

These results suggested a further investigation to include nitrogen, phosphate, potassium, and magnesium.

METHODS

The following methods of extraction were compared using 75 soil samples: a) saturation extract, b) 1:5 weight extract, and c) 1:2 volume extract.

Most samples were obtained from glasshouses, only a few being derived from outside. The soils were chosen to give as large a variation in soil type, salt and nutrient status as possible. One third of the samples were taken from sand or sandy-clay soils, one third from clay loams or clay soils and the remainder from peaty-clays or peat soils.

At the laboratory a sub-sample was dried at 45°C in order to prepare a 1:5 weight extract. The remainder was first examined for moisture content, and if this was considered to be low the soil was brought to field capacity with demineralised water. The moist soil was used to prepare both a saturation extract and a 1:2 volume extract.

Conductivity was recorded as mmho/cm at 25°C. The phosphate contents were expressed in mg P₂O₅ per litre, and the chloride, nitrogen, potassium and magnesium contents in me per litre. Methods of preparing the extracts and technique of determination have been described by Den Dekker and Van Dijk¹.

The organic matter content of the soils was determined by loss-of-weight on ignition, and is expressed as percent of air-dry soil. Soil moisture content was determined by drying at 105°C and is given as grams per 100 g dry soil (M-value).

RESULTS

Salt and nutrient status

The range and average values obtained from the different extracts are given in Table 1. The concentration in the extracts is shown to decrease with increasing water: soil ratio, the greatest effect being with nitrogen and chloride and the least effect with phosphate. The decrease in concentration with increasing water: soil ratio becomes clearly evident in the graphic presentation of results obtained for a sandy-clay soil having 5 per cent organic matter (Fig. 1A). For chloride and nitrogen the concentration was inversely proportional to the water: soil ratio (Fig. 1B), both being more or less totally dissolved in the soil solution. This is always true for chloride, and applies to nitrogen when present as nitrates, which is normally the case with many glasshouse soils. Values for conductivity, phosphate, potassium and magnesium, were higher than would have been expected purely from the dilution effect, dissolution of poorly soluble salts and release of adsorbed ions.

TABLE 1

Average values and limits of the analytical data of the different extracts

Determination	Saturation extract		1:2 volume extract		1:5 weight extract	
	Mean	Range	Mean	Range	Mean	Range
Conductivity mmho/cm (25°C)	4.43	0.58-12.16	2.01	0.24- 5.37	1.06	0.12- 3.49
Chloride me/l	8.12	0.50-56.33	2.72	0.16-15.42	1.35	0.08- 5.51
Nitrogen me/l	15.82	1.14-67.56	5.35	0.44-20.97	2.54	0.20-11.20
Phosphate mg P ₂ O ₅ /l	24.5	1.8 -99.6	19.7	1.6 -58.3	15.2	2.0 -45.6
Potassium me/l	5.35	0.37-32.12	2.58	0.21-11.98	1.32	0.12- 5.34
Magnesium me/l	10.40	0.54-40.96	4.07	0.17-17.06	1.99	0.12-10.30

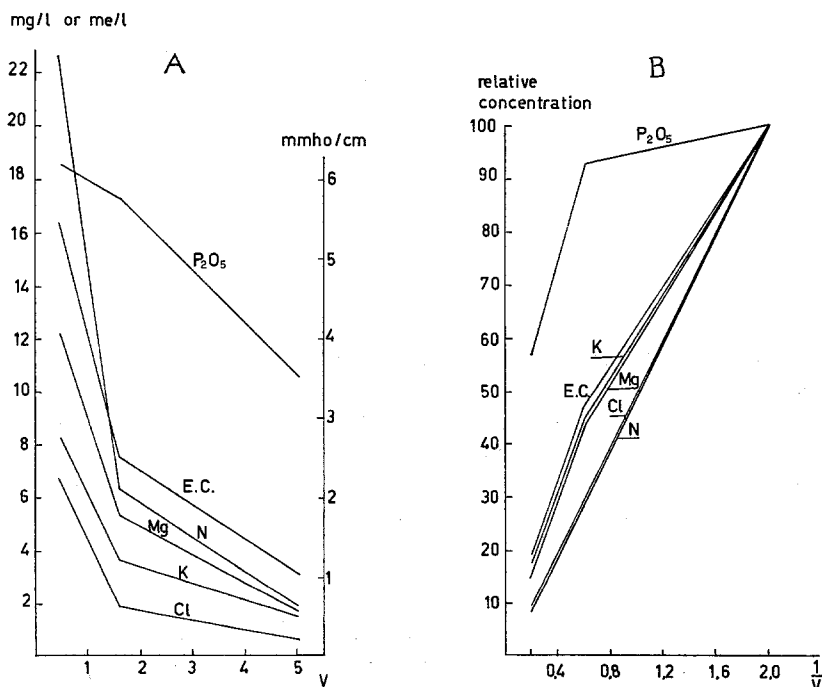


Fig. 1. **A.** The relationship between the ratio water: soil (V) and the analytical data of a sandy-clay soil. **B.** The relationship between the ratio soil: water ($1/V$) and the relative concentration of the analytical data of Fig. 1 A. The concentration of the saturation extract has been fixed at 100.

TABLE 2

Regression equations for the relationships between analytical data of saturation extract (x) and 1:2 volume extract (y)

Determination	Regression equation	Correlation coefficient
Conductivity	$y = 0.459x - 0.03$	0.948
Chloride	$y = 0.358x - 0.12$	0.976
Nitrogen	$y = 0.319x + 0.31$	0.982
Phosphate	$y = 0.637x + 4.42$	0.943
Potassium	$y = 0.442x + 0.25$	0.965
Magnesium	$y = 0.415x - 0.25$	0.960

Analytical data obtained by the different extracts have been compared by means of regression analysis. Before calculating the regression equations of few* very high results were omitted. Although even these high values were fairly closely connected to the regression line, they were omitted because the fit of the regression line in the range of horticulturally important values was none the less adversely affected. Regression equations giving the relationship between the analytical data of the saturation extracts and those for the 1:2 volume extracts are given in Table 2. Concentration of chloride and nitrogen in the 1:2 volume extract was about one third of that in the saturation extract, whilst for conductivity, potassium and magnesium, the values obtained from the 1:2 volume extract were relatively higher.

The high regression coefficient for phosphate was due to the large reserves of phosphate present in the soil, as a result of which the solution remained more or less phosphate-saturated with increasing water: soil ratio, and the high intercept was due to the fact that the relation between the correlated values was not strictly linear (Fig. 2).

Regression equations giving the relationship between analytical data obtained from the saturation extracts and the 1:5 weight extracts are given in Table 3. With the exception of phosphate, the results of determinations in the 1:5 weight extracts have first been corrected for the moisture content at field capacity. For advisory purposes the M-value at field capacity is calculated as follows:

* For conductivity, chloride and potassium the results of one sample and for phosphate the results of four samples.

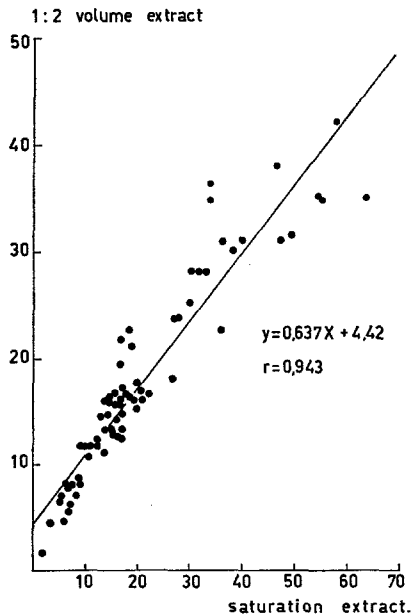


Fig. 2. The relationship between the phosphate content of saturation extract and 1:2 volume extract.

M-value = $2 \times$ percentage organic matter + 15 and the correction has been carried out by multiplication by the following factor:

$$p = \frac{100}{2q + 15} \quad (1)$$

in which p = correction factor, and q = percentage organic matter of the air-dry soil

Correlation coefficients between the saturation extracts and the 1:5 weight extracts are lower than those between the saturation extracts and the 1:2 volume extracts. Differences between the correlation coefficients due to methods of extraction are small for chloride, nitrogen and potassium (Tables 2 and 3), whilst for conductivity and phosphate the differences are appreciable, and favour the 1:2 volume extract. The lower correlation obtained for conductivity with the 1:5 weight extract was due to an increase in the amount of salts of low solubility – especially gypsum – whilst the lower correlation for phosphate was probably a consequence of drying the soil, which was only performed in preparation of the 1:5 weight

TABLE 3

Regression equations for the relationships between analytical data of saturation extract (x) and 1:5 weight extract (y). The analytical data of the 1:5 weight extract have been corrected on the organic matter content

Determination	Regression equation	Correlation coefficient
Conductivity	$y = 0.569x - 0.07$	0.870
Chloride	$y = 0.308x + 0.39$	0.951
Nitrogen	$y = 0.313x + 0.63$	0.976
Phosphate	$y = 0.370x + 6.57$	0.733
Potassium	$y = 0.481x + 0.54$	0.946
Magnesium	$y = 0.416x + 0.08$	0.924

extract. During drying the soluble phosphate of some soils is apparently partly fixed in such a manner that it does not readily redissolve; this is especially true of soils with a high soluble phosphate content. Van den Ende ² has also reported the phenomenon of phosphate fixation on drying.

The relationship between the 1:2 volume extract and saturation

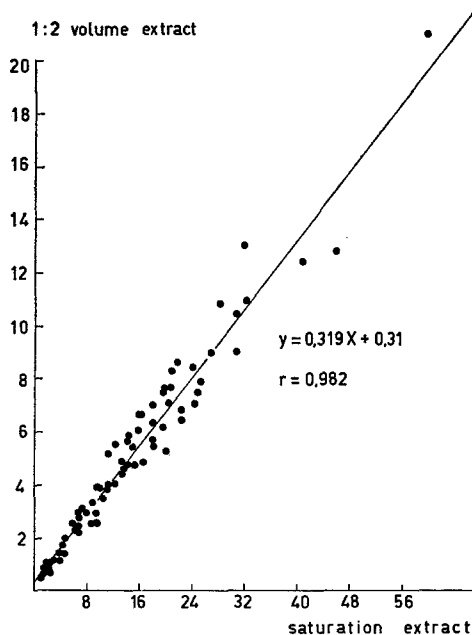


Fig. 3. The relationship between the nitrogen content of saturation extract and 1:2 volume extract.

extract for phosphate and nitrogen is shown in Figs. 2 and 3 respectively.

Organic matter and soil moisture

With the 1:2 volume extract the initial moisture content of the soil influences the analytical results, and for this reason soils at field capacity were used. It has been demonstrated by Van den Ende ² that the M-value at field capacity is closely related to the organic matter content, and this was also found to apply in the present investigation. The regression equation for the relationship being:

$$y = 2.71x + 10.7 \quad r = 0.972$$

in which x = percentage organic matter in the air-dry soil, and y = M-value of the soil at field capacity.

This equation agrees well with the equation found by Van den Ende. Glasshouse soils are frequently close to field capacity, and they can then be used for preparation of the 1:2 volume extract without any further moisture adjustment. In this investigation the moisture content was below field capacity for only a small number of samples, and these were adjusted by the addition of demineralised water. The evaluation of the moisture content of the soil was done visually and this gave good results (Fig. 4). When some experience has been obtained with visual evaluation of the moisture content it is unnecessary to determine M-value and organic matter content in preparing the 1:2 volume extract.

In utilizing the 1:2 volume extract a test of the visual evaluation against the derived regression equation will be useful. This can be made by determining the organic matter content and the M-value in random samples. As is also evident in Figure 4 the M-value found by determination will generally not be exactly the same as that obtained by calculation from the organic matter content. With a probability of $k\%$ the M-value found should lie between the confidence limits:

$$y_1 \pm \mu_k \cdot \sigma_{y_1} \quad (2)$$

in which y_1 = M-value calculated by means of the organic matter content, σ_{k1} = standard normal distributed quantity with a significance level of $k\%$, and σ_{y_1} = standard deviation of y_1 .

A good estimation of σ_{y_1} can be obtained from the data collected in this investigation by means of the following equation ⁵:

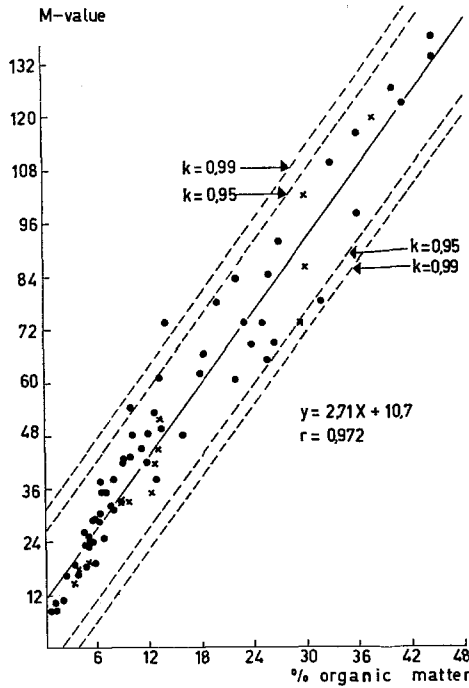


Fig. 4. The relationship between the organic matter content of the air-dry soil and the M-value of the field-moist soil (x = samples with corrected moisture content).

$$s_{y_1} = s_{y.x} \sqrt{1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{\sum (x - \bar{x})^2}} \tag{3}$$

in which s_{y_1} = estimation of σ_{y_1} , $s_{y.x}$ = sample standard deviation from regression, and n = number of observations.

Substituting the values obtained in this investigation we find:

$$s_{y_1} = 7.75 \sqrt{1 + \frac{1}{75} + \frac{(x - 14.8)^2}{10135}} \tag{4}$$

The confidence limits for the M-value called by means of this estimation are:

$$y_1 \pm t_k \cdot s_{y_1} \tag{5}$$

in which t_k = student distributed quantity with $n-2$ degrees of freedom and a significance level of $k\%$.

In Figure 4 the confidence limits are included for $k = 95\%$ and $k = 99\%$.

The weight ratio water: soil in the 1:2 volume suspension was determined, and as seen in Figure 5 shows a curvilinear relationship

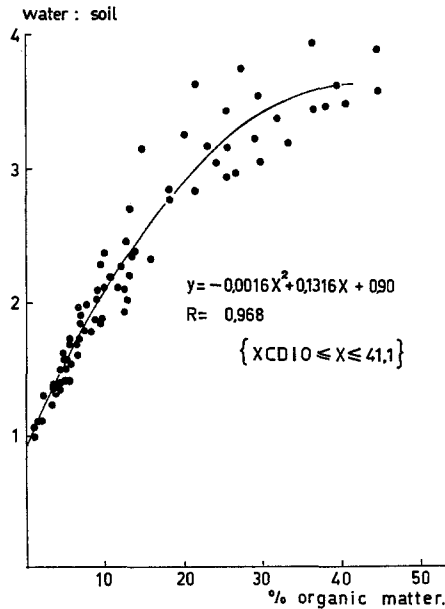


Fig. 5. The relationship between the organic matter content of the air-dry soil and the ratio water:soil of the 1:2 volume suspension.

with the organic matter content. One limitation in the calculated equation is the fact that the maximum is within the investigated range, which does not seem probable. The defined interval must therefore be limited.

The equation is:

$$y = -0.0016x^2 + 0.1316x + 0.90 \quad R = 0.968 \quad (6)$$

$$\{XCD | 0 \leq X \leq 41.1\}$$

in which x = organic matter content of the air-dry soil, y = water:soil ratio in the 1:2 volume suspension, and D = defined interval of the equation.

Interpretation

In applying the results derived from 1:2 volume extracts some guide or standard values are necessary. These can be derived from the existing standard values as used for the 1:5 weight extract by means of the regression equations in Table 4.

The following standard values are normally used with the 1:5

TABLE 4

Regression equations for the relationships between analytical data of 1:5 weight extract (x) and 1:2 volume extract (y). The analytical data of the 1:5 weight extract have been corrected on the organic matter content

Determination	Regression equation	Correlation coefficient
Conductivity	$y = 0.756x + 0.17$	0.885
Chloride	$y = 1.085x - 0.37$	0.958
Nitrogen	$y = 0.986x - 0.15$	0.974
Phosphate	$y = 1.080x + 2.31$	0.807
Potassium	$y = 0.831x + 0.01$	0.923
Magnesium	$y = 0.921x - 0.00$	0.960

weight extraction method:

$$\text{total salt} - \frac{(2 \times \text{percent organic matter} + 15)}{100} \%$$

$$\text{chloride} - (2 \times \text{percent organic matter} + 15) \text{ mg NaCl}/100 \text{ g}$$

$$\text{nitrogen} - \frac{(2 \times \text{percent organic matter} + 15)}{3} \text{ mg N}/100 \text{ g}$$

$$\text{phosphate} - 4 \text{ mg P}_2\text{O}_5/100 \text{ g}$$

$$\text{potassium} - \frac{(2 \times \text{percent organic matter} + 15)}{1.5} \text{ mg K}_2\text{O}/100 \text{ g}$$

$$\text{magnesium} - \frac{(2 \times \text{percent organic matter} + 15)}{3} \text{ mg MgO}/100 \text{ g}$$

TABLE 5

The standard values for analytical results of 1:5 weight extract and 1:2 volume extract. The standard values for the analytical results of the 1:5 weight extract have been corrected on the organic matter content

Determination	Standard values	
	1:5 weight extract	1:2 volume extract
Conductivity	2.61 mmho (25°C)	2.14 mmho (25°C)
Chloride	3.42 me Cl/l	3.34 me Cl/l
Nitrogen	4.76 me N/l	4.54 me N/l
Phosphate	8.0 mg P ₂ O ₅ /l	11.0 mg P ₂ O ₅ /l
Potassium	2.84 me K/l	2.37 me K/l
Magnesium	3.30 me Mg/l	3.04 me Mg/l

All these contents are expressed on the basis of air-dry soil.

These standard values, used for advisory purposes, have been converted to the units used in this investigation and together with the derived standard values for the 1:2 volume extract are presented in Table 5.

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